National Aeronautics and Space Administration

PRESS KIT/APRIL 2014

SPACEX CRS-3 MISSION

CARGO RESUPPLY SERVICES MISSION

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SPACEX

SpaceX CRS-3 Mission Press Kit

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HIGH RESOLUTION PHOTOS AND VIDEO

SpaceX will post photos and video throughout the mission.

High-resolution photographs can be downloaded from: spacex.com/media
Broadcast quality video can be downloaded from: vimeo.com/spacexlaunch/

MORE RESOURCES ON THE WEB

For SpaceX coverage, visit:

spacex.com
twitter.com/elonmusk
twitter.com/spacex
facebook.com/spacex
plus.google.com/+SpaceX
youtube.com/spacex

For NASA coverage, visit:

www.nasa.gov/station
www.nasa.gov/nasatv
twitter.com/nasa
facebook.com/ISS
plus.google.com/+NASA
youtube.com/nasatelevision

WEBCAST INFORMATION

The launch will be webcast live, with commentary from SpaceX corporate headquarters in Hawthorne, CA, at spacex.com/webcast and NASA's Kennedy Space Center at www.nasa.gov/nasatv.

Web pre-launch coverage will begin at approximately 3:30 p.m. EDT.

The official SpaceX webcast will begin approximately 40 minutes before launch.

SpaceX hosts will provide information specific to the flight, an overview of the Falcon 9 rocket and Dragon spacecraft, and commentary on the launch and flight sequences.

SpaceX CRS-3 Mission Overview

Overview

After three successful missions to the International Space Station, including two official resupply missions for NASA, SpaceX is set to launch its third Commercial Resupply (CRS) mission to the orbiting lab. The SpaceX CRS-3 mission is targeting launch at 4:58 p.m. EDT Monday, April 14 from Launch Complex 40 at the Cape Canaveral Air Force Station, Florida.

If all goes as planned, Dragon will arrive at the station on Wednesday, April 16, when it will be grappled and berthed to the orbiting laboratory for an expected four-week visit. Dragon is scheduled to return to Earth approximately 20 to 30 days later for a parachute-assisted splashdown off the coast of southern California. Dragon is the only space station cargo craft capable of returning a significant amount of supplies back to Earth, including experiments.

Background and Purpose

SpaceX CRS-3 is the third of at least 12 missions to the International Space Station that SpaceX will fly for NASA under the Commercial Resupply Services (CRS) contract. In December 2008, NASA announced that SpaceX's Falcon 9 launch vehicle and Dragon spacecraft had been selected to resupply the space station after the end of the Space Shuttle program in 2011. Under the CRS contract, SpaceX is restoring an American capability to deliver and return significant amounts of cargo, which could include live plants and animals, to and from the orbiting laboratory.

Cargo

Dragon will be filled with nearly 5,000 pounds of supplies and payloads, including critical materials to support more than 150 investigations that will occur during Expeditions 39 and 40. Dragon will carry four powered cargo payloads in its pressurized section and two in its unpressurized trunk, a first for SpaceX. Dragon will return with about 3,600 pounds of cargo, which includes crew supplies, hardware and computer resources, science experiments, biotechnology, and space station hardware.

Science payloads include the Optical Payload for Lasercomm Science (OPALS), which will test the use of laser optics to transfer information to Earth from space; the Vegetable Production System (VEGGIE), a unit capable of producing salad-type vegetables in space; and the National Institutes of Health-funded T-Cell Activation in Aging experiment that seeks the cause of a depression in the human immune system that occur during aging and while astronauts are in microgravity. In addition, the High Definition Earth Viewing (HDEV) investigation includes four high-definition cameras to be placed on the space station's exterior for use in streaming live video of Earth for online viewing.

Secondary Payloads

Falcon 9 will deliver five CubeSats to orbit as part of the CRS-3 mission, contained in four Poly Picosatellite Orbital Deployers (P-PODs).

A Challenging Mission

All spaceflight is incredibly complicated, from launch to recovery. Every component of the mission must operate optimally. Hardware, avionics, sensors, software and communications must function together flawlessly. If any aspect of the mission is not successful, SpaceX and NASA will learn from the experience and try again.

Prelaunch

Months before a Falcon 9 launch, both rocket stages are transported to SpaceX's Rocket Development Facility in McGregor, Texas for testing, and then trucked individually to SpaceX's hangar at Space Launch Complex 40 at Cape Canaveral, Florida. There, the stages are integrated and Dragon receives its cargo. The final major preflight test is a static fire, when Falcon 9's nine first-stage engines are ignited for a few seconds, with the vehicle held securely to the pad.

Key NASA and SpaceX personnel determine the design of the rendezvous profile, including both the timing and path of Dragon's approach to the space station. SpaceX also works with NASA to analyze and integrate each piece of cargo that is to be delivered to and from the station. About two weeks before launch, a formal Stage Operations Readiness Review is conducted, involving representatives from all five of the space station's international partner agencies: NASA, the Canadian Space Agency (CSA), the European Space Agency (ESA), the Japan Aerospace Exploration Agency (JAXA), and the Russian Federal Space Agency (Roscosmos), to ensure the launch vehicle, spacecraft, cargo, space station, and launch and operations teams are ready for the mission.

On launch day, Falcon 9, with Dragon mated, is again transported to the launch pad. All ground personnel leave the pad in preparation for fueling, which proceeds automatically.

Launch Sequence

The launch sequence for Falcon 9 is a process of clockwork precision necessitated by the rocket's instantaneous launch window—that is, everything is timed to the exact second of scheduled liftoff. Because an off-time liftoff would require Dragon to use extra propellant to reach the space station, the launch window must be hit precisely. If not, the mission will be attempted on another day.

Fifteen hours before launch, Dragon is powered up in preparation for the NASA powered cargo delivery and loading. A little less than four hours before launch, the fueling process begins—RP-1 kerosene propellant first, then liquid oxygen. The plume coming off the vehicle during countdown is gaseous oxygen being vented from the tanks, which is why the liquid oxygen is topped off throughout the countdown.

Terminal countdown begins at T-10 minutes, at which point all systems are autonomous. After polling Mission Control in Hawthorne, California, and the launch team at Cape Canaveral, the Launch Director gives a final go for launch at T-2 minutes and 30 seconds. At T-2 minutes, the Air Force Range Control Officer confirms the physical safety of the launch area and provides the final range status. Just before liftoff, the launch pad's water deluge system, dubbed "Niagara," is activated.

Seconds before launch, the nine Merlin engines of the first stage ignite. The rocket computer commands the launch mount to release the vehicle for flight, and at T-0, Falcon 9 lifts off, putting out just over 1.3 million pounds of thrust.

Launch and Ascent

One minute and 10 seconds after liftoff, Falcon 9 reaches supersonic speed. The vehicle will pass through the area of maximum aerodynamic pressure—max Q—roughly 13 seconds later. This is the point when mechanical stress on the rocket peaks due to a combination of the rocket's velocity and resistance created by the Earth's atmosphere.

Approximately 161 seconds into flight, the first-stage engines are shut down, an event known as main-engine cutoff, or MECO. At this point, Falcon 9 is 80 kilometers (50 miles) high, traveling at 10 times the speed of sound. Three seconds after MECO, the first and second stages will separate. One second later, the second stage's single Merlin vacuum engine ignites to begin a six-minute burn that brings Falcon 9 and Dragon into low-Earth orbit.

Forty seconds after second-stage ignition, Dragon's protective nose cone, which covers Dragon's berthing mechanism, will be jettisoned. Nine minutes and 40 seconds after launch, the second-stage engine cuts off (SECO). Thirty-five seconds later, Dragon separates from Falcon 9's second stage and achieves its preliminary orbit. It then deploys its solar arrays, and begins a carefully choreographed series of Draco thruster firings to reach the space station. The P-PODs will also be deployed from the second stage following Dragon separation.

Approach to Station

As Dragon chases the station, the spacecraft will establish UHF communication using its COTS Ultra-high-frequency Communication Unit (CUCU). Also, using the crew command panel (CCP) on board the station, the space station crew will interact with Dragon to monitor the approach. This ability for the crew to send commands to Dragon will be important during the rendezvous and departure phases of the mission.

During final approach to the station, a go/no-go is performed by Mission Control in Houston and the SpaceX team in Hawthorne to allow Dragon to perform another engine burn that will bring it 250 meters (820 feet) from the station. At this distance, Dragon will begin using its close-range guidance systems, composed of LIDAR and thermal imagers. These systems will confirm that Dragon's position and velocity are accurate by comparing the LIDAR image that Dragon receives against Dragon's thermal imagers. Using the Crew Command Panel, the ISS crew, monitored by the Dragon flight control team in Hawthorne and the NASA flight control team at the Johnson Space Center's International Space Station Flight Control Room, will command the spacecraft to approach the station from its hold position.

After another go/no-go is performed by the Houston and Hawthorne teams, Dragon is permitted to enter the Keep-Out Sphere (KOS), an imaginary sphere drawn 200 meters (656 feet) around the station within which the Dragon approach is monitored very carefully to minimize the risk of collision. Dragon will proceed to a position 30 meters (98 feet) from the station and will automatically hold. Another go/no-go is completed. Then Dragon will proceed to the 10-meter (32 feet) position—the capture point. A final go/no-go is performed, and the Mission Control Houston team will notify the crew they are go to capture Dragon.

Capture and Berthing

At that point, Expedition 38 Commander Koichi Wakata, with assistance from Flight Engineer Rick Mastracchio, will use the station's 17.6-meter (57.7-foot) robotic arm to reach out and capture the Dragon spacecraft. Ground commands will be sent from Houston for the station's arm to rotate Dragon around and install it on the bottom side of the station's Harmony module, enabling it to be bolted in place for its stay at the International Space Station.

By the next day, crew will pressurize the vestibule between the station and Dragon and will open the hatch that leads to the forward bulkhead of Dragon. The crew will work over the next four weeks to unload Dragon's payload and reload it with cargo that Dragon will bring back to Earth.

Return Flight

After its mission at the orbital laboratory is completed, Mission Control Houston will send commands to detach Dragon from Harmony, maneuver it away from the station with the robotic arm to the 15-meter release point, and then the crew will release the vehicle via commands from the Crew Command Panel. Dragon will perform a series of three burns to place it on a trajectory away from the station. Mission Control Houston will then confirm that Dragon is on a safe path away from the station.

Approximately five hours after Dragon leaves the station, it will conduct its deorbit burn, which lasts up to 10 minutes. It takes about 30 minutes for Dragon to reenter the Earth's atmosphere, allowing it to splash down in the Pacific Ocean, about 630 kilometers (340 nautical miles) off the coast of California.

Dragon Recovery

Dragon's landing is controlled by automatic firing of its Draco thrusters during reentry. In a carefully timed sequence of events, dual drogue parachutes deploy at 13,700 meters (45,000 feet) to stabilize and slow the spacecraft.

Full deployment of the drogues triggers the release of the three main parachutes, each 35 meters (116 feet) in diameter, at about 3,000 meters (10,000 feet). While the drogues detach from the spacecraft, these main parachutes further slow the spacecraft's descent to approximately 4.8 to 5.4 meters per second (16 to 18 feet per second). Even if Dragon were to lose one of its main parachutes, the two remaining chutes would still permit a safe landing.

SpaceX will use a 100-foot boat equipped with an A-frame crane and two inflatable boats to perform recovery operations. On board will be approximately a dozen SpaceX engineers and technicians as well as a four-person dive team. Once Dragon splashes down, the team will first secure the vehicle and then place it on deck for the journey back to shore.

Mission Timeline

Times and dates are subject to change.

Day 1: LAUNCH

COUNTDOWN

Hour/Min	Events
- 15:30	Dragon is powered on
- 10:00	Falcon 9 is powered on
- 4:00	Commence loading RP-1 (rocket grade kerosene)
- 3:20	Commence loading liquid oxygen (LOX)
- 3:15	LOX and RP-1 loading complete
- 0:10	Falcon 9 terminal count autosequence started
- 0:06	Dragon terminal count autosequence started
- 0:02	SpaceX Launch Director verifies go for launch
- 0:02	Range Control Officer (USAF) verifies range is go for launch
- 0:01	Command flight computer to begin final prelaunch checks. Turn on pad deck and Niagara water
- 0:00:40	Pressurize propellant tanks
- 0:00:03	Engine controller commands engine ignition sequence to start
0:00	Falcon 9 liftoff

LAUNCH

Hour/Min	Events
0:01	Max Q (moment of peak mechanical stress on the rocket)
0:03	1st stage engine shutdown/main engine cutoff (MECO)
0:03	1st and 2nd stages separate
0:03	2nd stage engine starts
0:03	Dragon nose cone jettisoned
0:09	2nd stage engine cutoff (SECO)
0:09	Dragon separates from 2nd stage
0:10	P-POD Deployment

DRAGON ON-ORBIT OPERATIONS AND APPROACH TO STATION

Hour/Min	Events
0:11	Start sequence to deploy solar arrays
1:50	Coelliptic burn; circularizes orbit after Falcon 9 injection
2:26	Start GNC (guidance and navigation control) bay door deployment—this exposes sensors necessary for rendezvous.

Day 2: HEIGHT ADJUST MANEUVERS TO R-BAR AND CAPTURE

(R-Bar - Radial Bar - is an imaginary line connecting station to the center of the Earth)

- Height adjust burns start adjusting altitude higher toward station

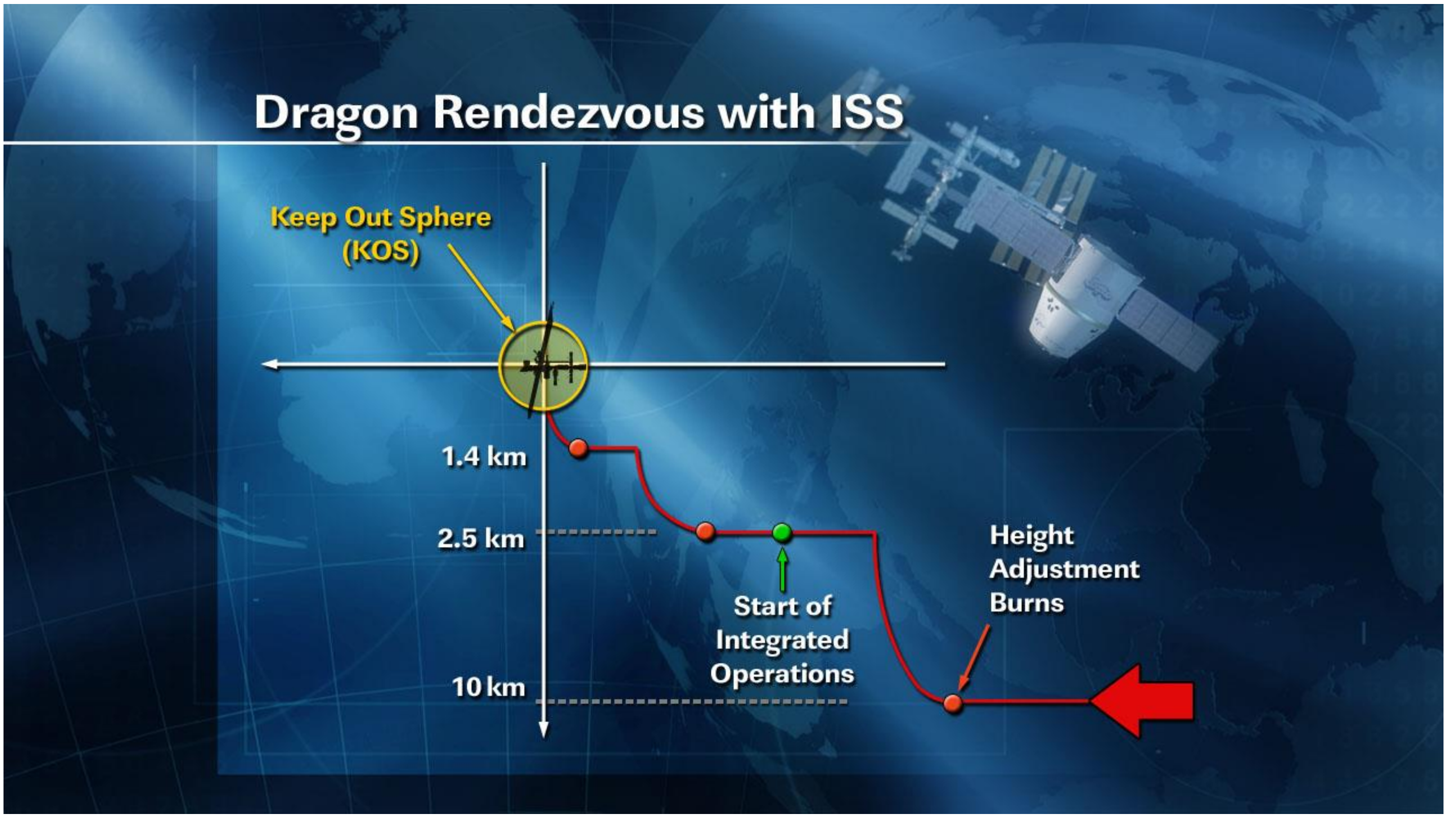
- COTS Ultra-high Frequency Communication Unit (CUCU) and Dragon UHF communication systems are configured for ISS to Dragon communication.
- Height adjust burn: Dragon begins burns that bring it within 2.5 km altitude below station (go/no-go)
- Dragon receives and sends information from/to the CUCU unit on station
- Height adjust burn brings Dragon 1.2 km altitude below station (go/no-go)
- Height adjust burn carries Dragon into the station's approach ellipsoid (go/no-go)
- Dragon holds at 250 meters (go/no-go) for confirmation of proximity sensors targeting acquisition
- Dragon begins R-Bar Approach
- Dragon holds at 30 meters (go/no-go)
- Dragon holds at capture point, 10 meters below the station (go/no-go)
- Crew captures Dragon using the station's robotic arm (SSRMS)
- Dragon is attached to the station with hatch opening complete by Day 3

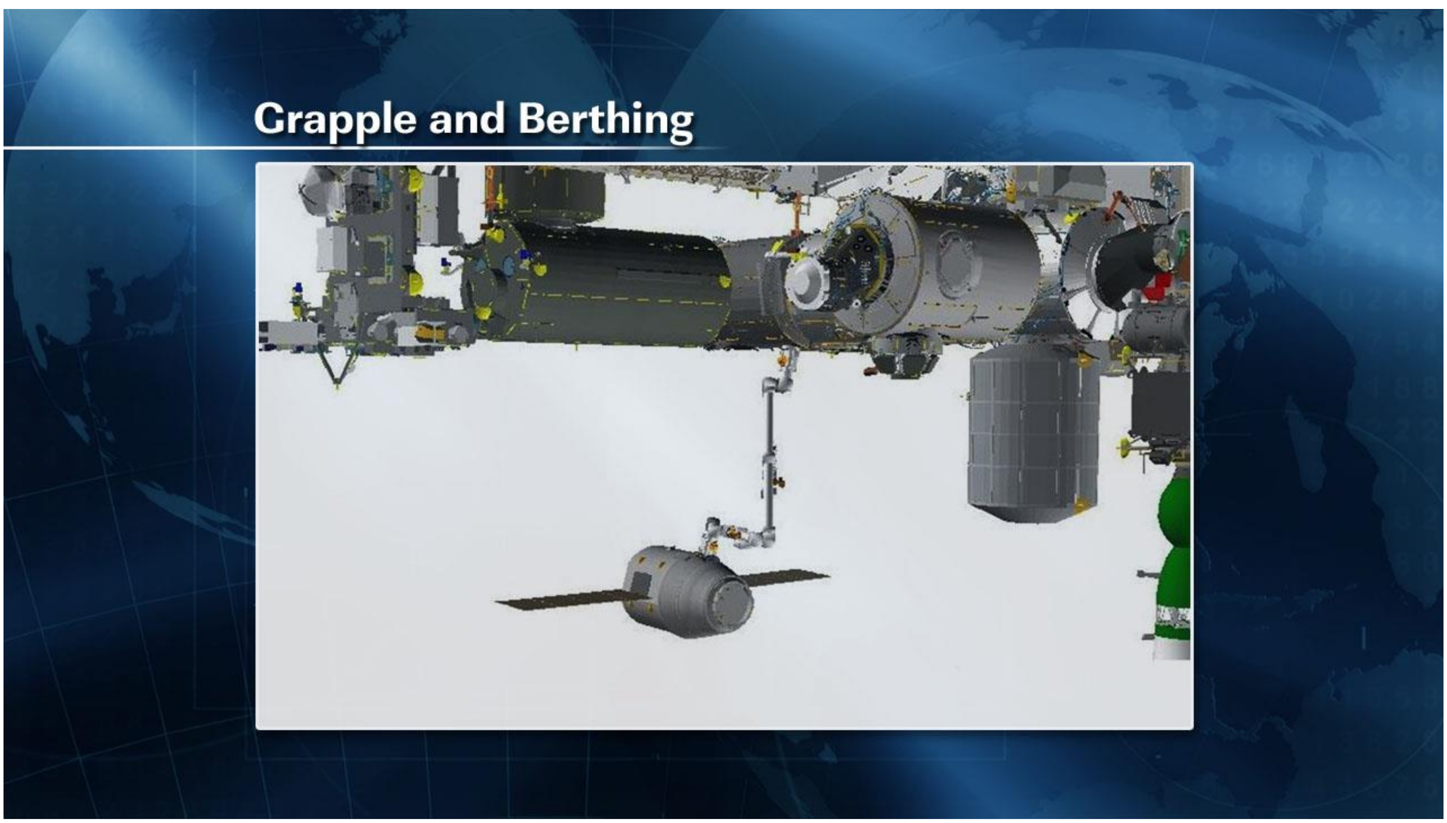
RETURN DAY -1

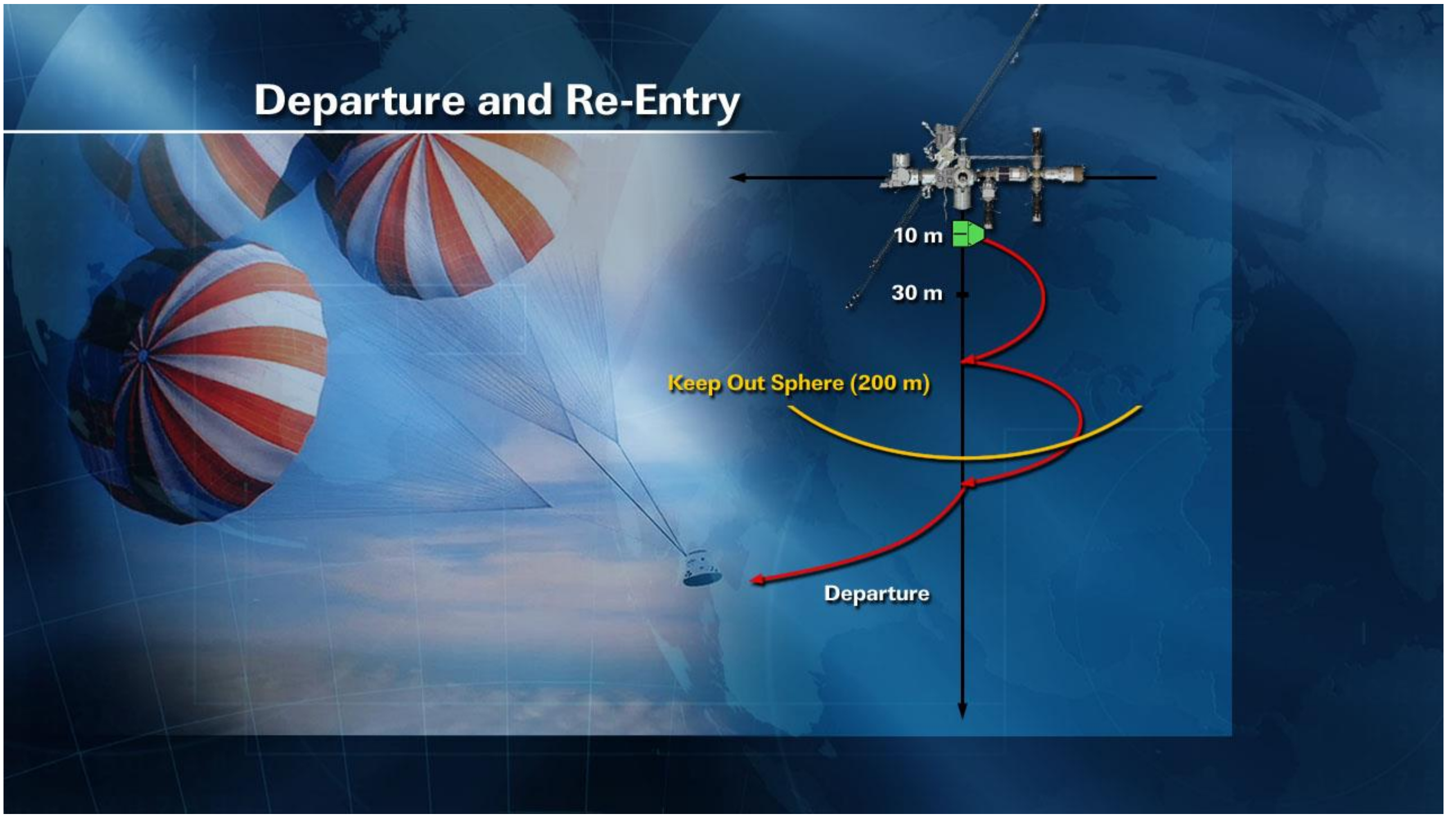
- Dragon checkouts
- Late load return cargo stowed in Dragon
- Hatch is closed

RETURN

- Dragon vestibule de-mate and depressurization
- Station's robotic arm uninstalls Dragon
- Robotic arm releases Dragon
- Crew commands the departure
- Dragon starts departure burns
- Dragon closes the guidance, navigation, and control bay door
- Deorbit burn
- Trunk jettisoned
- Drogue chutes deployed
- Main chutes deployed
- Dragon lands in water and is recovered


Dragon Rendezvous with ISS
Keep Out Sphere
(KOS)
1.4 km
2.5 km
10 km
Start of
Integrated
Operations
Height
Adjustment
Burns


Grapple and Berthing


Departure and Re-Entry
10 m
30 m
Keep Out Sphere (200 m)
Departure

International Space Station Overview

The International Space Station is an unprecedented achievement in global human endeavors to conceive, plan, build, operate and use a research platform in space.

Almost as soon as the space station was habitable, researchers began using it to study the impact of microgravity and other space effects on several aspects of our daily lives. With almost 1,500 experiments completed on the station to date, the unique scientific platform continues to enable researchers from all over the world to put their talents to work on innovative experiments that could not be performed anywhere else.

The space station represents the culmination of more than two decades of dedicated effort by a multinational team of agencies spanning Canada, Europe, Japan, Russia and the United States. While the various space agency partners may emphasize different aspects of research to achieve their goals in the use of space station, they are unified in using the space station to its full potential as a research platform for the betterment of humanity.

The space station provides the first laboratory complex where gravity, a fundamental force on Earth, is virtually eliminated for extended periods. This ability to control the variable of gravity in experiments opens up unimaginable research possibilities. As a research outpost, the station is a test bed for future technologies and a laboratory for new, advanced industrial materials, communications technology, medical research, and more.

In the areas of human health, telemedicine, education and observations from space, the station already has provided numerous benefits to human life on Earth. Vaccine development research, station-generated images that assist with disaster relief and farming, and education programs that inspire future scientists, engineers and space explorers are just some examples of research benefits, which are strengthening economies and enhancing the quality of life on Earth. Clearly visible with the naked eye in the night sky, the expansive International Space Station is a working laboratory orbiting approximately 260 miles above the Earth traveling at 17,500 miles per hour and is home to an international crew.

The most complex scientific and technological endeavor ever undertaken, the five supporting agencies represent 15 nations: the U.S., Canada, Japan, Russia, Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom.

Assembly in space began in November 1998 with the launch of its first module, Zarya, and was completed with the departure of the Space Shuttle Atlantis on the program’s final flight in June 2011. The station is as large as a five-bedroom home with two bathrooms, a gymnasium and a 360-degree bay window, and provides crew members with more than 33,000 cubic feet (935 cubic meters) of habitable volume. The station weighs nearly 1 million pounds (419,600 kilograms) and measures 361 feet (110.03 meters) end to end, which is equivalent to a U.S. football field including the end zones. The station’s solar panels exceed the wingspan of a Boeing 777 jetliner and harness enough energy from the sun to provide electrical power to all station components and scientific experiments.

The station now includes the Russian-built Zarya, Zvezda, Pirs, Poisk and Rassvet modules; the U.S.-built Unity, and Harmony connection modules, the Quest airlock module, the Tranquility module and its 360-degree-view cupola, and the Permanent Multipurpose Module. Research facilities populate the U.S. Destiny Laboratory, the European Columbus Laboratory, and the Japanese Kibo laboratory and external experiment platform. The Canadian-provided Canadarm2 robotic arm and its Mobile Servicing System give the station a movable space crane, and the Special Purpose Dexterous Manipulator, or Dextre, provides a smaller two-armed robot capable of handling delicate assembly tasks. This space cherry-picker can move along the Integrated Truss Structure, forms the backbone of the station, and connects the station’s solar arrays, cooling radiators and spare part platforms.

The station’s first resident crew, Expedition 1, marked the beginning of a permanent international human presence in space, arriving at the station in a Russian Soyuz capsule in November 2000. For more than 13 years, station crews have provided a continuous human presence in space, with crews averaging six months at a time though the current 39th expedition.

Earlier this year, the Obama Administration approved an extension of the International Space Station until at least 2024. The decision will allow NASA to maximize its potential, deliver critical benefits to our nation and the world and maintain American leadership in space. This extension will give the agency and its private sector partners sufficient time to fully transition low-Earth orbit cargo transportation, research experiments and crew to the commercial space industry so that NASA can continue to focus on developing the next generation heavy-lift rocket and crew capsule necessary for deep space exploration.

Extending the life of the space station another decade will allow NASA to complete necessary technological and human research activities aboard the orbital laboratory that are associated with planned long-duration human missions beyond low-Earth orbit, including a planned human mission to an asteroid by 2025 and to Mars in the 2030s.

With the assembly of the space station at its completion and the support of a full-time crew of six, a new era of utilization for research is beginning. During the space station assembly phase, the potential benefits of space-based research and development were demonstrated, including the advancement of scientific knowledge based on experiments conducted in space, development and testing of new technologies, and derivation of Earth applications from new understanding.

The space station also is a vital precursor for future human exploration, where humans are learning how to combat the psychological and physiological effects of being in space for long periods, conducting both fundamental and applied research, testing technologies and decision-making processes.

The 2005 NASA Authorization Act designated the U.S. segment of the space station as a national laboratory. As the Nation's only national laboratory on-orbit, the space station National Lab fosters relationships among NASA, other federal entities, and the private sector, and advances science, technology, engineering and mathematics education through utilization of the space station's unique capabilities as a permanent microgravity platform with exposure to the space environment. NASA's research goals for the space station are driven by the NASA Authorization Act of 2010 and are focused on the following four areas: human health and exploration, technology testing for enabling future exploration, research in basic life and physical sciences, and earth and space science.

The International Space Station Program’s greatest accomplishment is as much a human achievement as it is a technological one—how best to plan, coordinate, and monitor the varied activities of the Program’s many organizations. The program brings together international flight crews; multiple launch vehicles; globally distributed launch, operations, training, engineering, and development facilities; communications networks; and the international scientific research community.

Elements launched from different countries and continents are not mated together until they reach orbit, and some elements that have been launched later in the assembly sequence were not yet built when the first elements were placed in orbit.

Construction, assembly and operation of the International Space Station requires the support of facilities on the Earth managed by all of the international partner agencies and countries involved in the program. These include construction facilities, launch support and processing facilities, mission operations support facilities, research and technology development facilities and communications facilities.
Operating the space station is even more complicated than other space flight endeavors because it is an international program. Each partner has the primary responsibility to manage and run the hardware it provides. The addition of commercial partners as providers of resupply and, in the future, crew transportation services, adds a new dimension to this complexity.

Falcon 9 Rocket

Falcon 9 is a two-stage rocket designed from the ground up by SpaceX for the reliable and cost-efficient transport of satellites and SpaceX's Dragon spacecraft.

QUICK FACTS

Made in America. All of Falcon 9's structures, engines, separation systems, ground systems, and most avionics were designed, manufactured, and tested in the United States by SpaceX.

21st-century rocket. As the first rocket completely developed in the 21st century, Falcon 9 was designed from the ground up for maximum reliability. An upgraded Falcon 9 with safety and reliability enhancements and greater lift capability flew for the first time in September 2013, lofting the CASSIOPE satellite to low-Earth orbit, and will fly on this mission.

Designed for maximum reliability. Falcon 9 features a simple two-stage design to minimize the number of stage separations. (Historically, the main causes of launch failures have been stage separations and engine failures.) With nine engines on the first stage, it can safely complete its mission even in the event of an engine shutdown.

Statistics. Falcon 9 topped with Dragon is 207.8 feet (63.3 meters) tall and 12 feet in diameter. Its nine first-stage Merlin engines generate just over 1.3 million pounds of thrust at sea level, rising to 1.5 million pounds of thrust as Falcon 9 climbs out of the Earth's atmosphere.

In demand. SpaceX has nearly fifty Falcon 9 missions on its manifest, with launches for both commercial and government clients.

Designed to safely transport crew. Like the Dragon spacecraft, Falcon 9 was designed from the outset to transport crew to space.

Mission success. Falcon 9 has achieved 100% mission success on its flights to date, including routine flights to the International Space Station and most recently the successful January 2014 launch of the THAICOM-6 satellite to geosynchronous transfer orbit.

Why "Falcon"? Falcon 9 is named for the Millennium Falcon in the "Star Wars" movies. The number 9 refers to the nine Merlin engines that power Falcon 9's first stage; one Merlin vacuum engine powers the second stage.

National Aeronautics and Space Administration

ADVANCED TECHNOLOGY

First Stage

Falcon 9 tanks are made of aluminum-lithium alloy, a material made stronger and lighter than aluminum by the addition of lithium. Inside the two stages are two large tanks each capped with an aluminum dome, which store liquid oxygen and rocket-grade kerosene (RP-1) engine propellants.

The tanks and domes are fabricated entirely in-house by SpaceX. Sections of aluminum are joined together using SpaceX's custom-made friction stir welders to execute the strongest and most reliable welding technique available. The structures are painted in-house by SpaceX, concurrent with the welding process.

Falcon 9's first stage incorporates nine Merlin engines. After ignition, a hold-before-release system ensures that all engines are verified for full-thrust performance before the rocket is released for flight. Then, with thrust greater than five 747s at full power, the Merlin engines launch the rocket to space. Unlike airplanes, a rocket's thrust actually increases with altitude. Falcon 9 generates just over 1.3 million pounds of thrust at sea level but gets up to 1.5 million pounds of thrust in the vacuum of space. The first stage engines are gradually throttled near the end of first-stage flight to limit launch vehicle acceleration as the rocket's mass decreases with the burning of fuel.

Interstage

The interstage, which connects the first and second stages, is a composite structure made of sheets of carbon fiber and an aluminum honeycomb core, and it holds the release and separation system. Falcon 9 uses an all-pneumatic stage separation system for low-shock, highly reliable separation that can be tested on the ground, unlike pyrotechnic systems used on most launch vehicles.

Second Stage

The second stage, powered by a single Merlin vacuum engine, delivers Falcon 9's payload to the desired orbit. The second stage engine ignites a few seconds after stage separation, and can be restarted multiple times to place multiple payloads into different orbits.

Like the first stage, the second stage is made from a high-strength aluminum-lithium alloy, using most of the same tooling, materials, and manufacturing techniques. This commonality yields significant design and manufacturing efficiencies.

Merlin 1D Engine

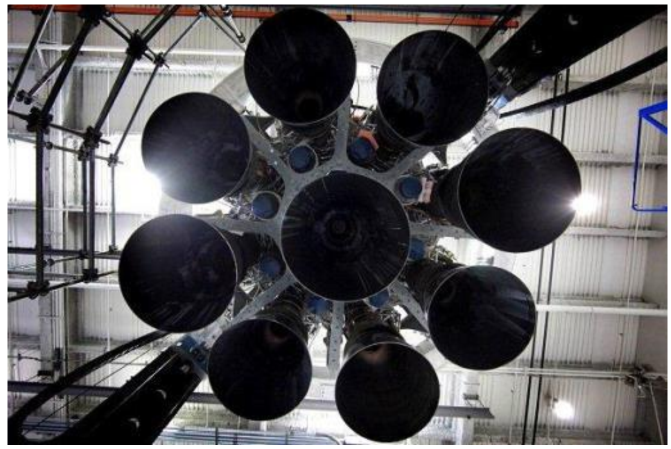
The Merlin engine that powers the first stage of Falcon 9 is developed and manufactured in-house by SpaceX . Burning liquid oxygen and rocket-grade kerosene propellant, a single Merlin engine generates 654 kilonewtons (147,000 pounds) of thrust at liftoff, rising to 716 kilonewtons (161,000 pounds) as it climbs out of Earth's atmosphere. Merlin's thrust-to-weight ratio exceeds 150, making the Merlin the most efficient booster engine ever built, while still maintaining the structural and thermal safety margins needed to carry astronauts.

Falcon 9 is the only vehicle currently flying with engine out capability. The nine-engine architecture on the first stage is an improved version of the design employed by the Saturn I and Saturn V rockets of the Apollo program, which had flawless flight records in spite of engine losses.

The Merlin 1D engine provides a number of improvements over its Merlin 1C predecessor, including greater performance, improved manufacturability by using high efficiency processes, increased robotic construction and reduced parts count.

High-pressure liquid oxygen and kerosene propellant are fed to each engine via a single-shaft, dual-impeller turbopump operating on a gas generator cycle. Kerosene from the turbopump also serves as the hydraulic fluid for the thrust vector control actuators on each engine, and is then recycled into the low-pressure inlet. This design eliminates the need for a separate hydraulic power system, and eliminates the risk of hydraulic fluid depletion. Kerosene is also used for regenerative cooling of the thrust chamber and expansion nozzle.

Octaweb



The Octaweb thrust structure of the nine Merlin engines improves upon the former 3x3 engine arrangement, increasing the Falcon 9's reliability while streamlining its manufacturing process. It houses the nine Merlin 1D engines and was designed to handle the increase in thrust from the Merlin 1C to Merlin 1D engine design. To form the structure, sheet metal is welded together and engines are placed into the nine slots. The eight engines surrounding one center engine simplify the design and assembly of the engine section, reducing production time from about three months to a matter of weeks.

The new layout also provides individual protection for each engine, and further protects other engines in case of an engine failure. It significantly reduces both the length and weight of the Falcon 9 first stage thrust structure. With this design, Falcon 9 is also prepared for reusability – the Octaweb will be able to survive the first stage's return to Earth post-launch.

Reliability

This flight represents the ninth flight of the Falcon 9, following eight successful missions.

An analysis of launch failure history between 1980 and 1999 by the Aerospace Corporation showed that 91% of known failures can be attributed to three causes: engine failure, stage-separation failure, and, to a much lesser degree, avionics failure. Because Falcon has nine Merlin engines clustered together to power the first stage, the vehicle is capable of sustaining certain engine failures and still completing its mission. This is an improved version of the architecture employed by the Saturn I and Saturn V rockets of the Apollo program, which had flawless flight records despite the loss of engines on a number of missions. With only two stages, Falcon 9 limits problems associated with separation events.

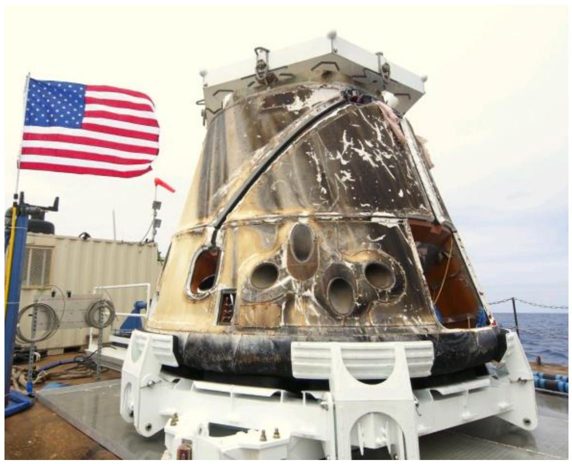
SpaceX maximizes design and in-house production of much of Falcon 9's avionics, helping ensure compatibility among the rocket engines, propellant tanks, and electronics. In addition, SpaceX has a complete hardware simulator of the avionics in its Hawthorne factory. This simulator, utilizing electronics identical to those on the rocket, allows SpaceX to check nominal and off-nominal flight sequences and validate the data that will be used to guide the rocket.

SpaceX uses a hold-before-release system—a capability required by commercial airplanes, but not implemented on many launch vehicles. After the first-stage engines ignite, Falcon 9 is held down and not released for flight until all propulsion and vehicle systems are confirmed to be operating normally. An automatic safe shutdown occurs and propellant is unloaded if any issues are detected.

Dragon Spacecraft

Dragon is a free-flying, reusable spacecraft developed to carry cargo, and eventually astronauts, into space.

QUICK FACTS



Built by SpaceX from the ground up. SpaceX developed Dragon from a blank sheet to its first mission in just over four years.

First privately developed spacecraft to attach to the International Space Station (ISS). In May 2012, Dragon became the first commercial spacecraft to deliver cargo to the ISS and return safely to Earth, a feat previously achieved only by governments. In October 2012, Dragon completed its second mission to the ISS, its first of 12 official cargo resupply missions for NASA.

Payload capability. Dragon carries cargo in a pressurized capsule and an unpressurized trunk. It can carry 6,000 kilograms (13,228 pounds), split between pressurized cargo inside the capsule and unpressurized cargo in the trunk, which also houses Dragon's solar panels.

Dimensions. Dragon is 4.4 meters (14.4 feet) tall and 3.66 meters (12 feet) in diameter. The trunk is 2.8 meters (9.2 feet) tall and 3.66 meters (12 feet) wide. With solar panels fully extended, the vehicle measures 16.5 meters (54 feet) wide.

Advanced heat shield. Dragon has the most effective heat shield in the world. Designed with NASA and fabricated by SpaceX, it is made of PICA-X, a high-performance variant on NASA's original phenolic impregnated carbon ablator (PICA). PICA-X is designed to withstand heat rates from a lunar return mission, which far exceed the requirements for a low-Earth orbit mission.

Smooth, controlled reentry. Dragon's passively stable shape generates lift as it reenters the Earth's atmosphere. Its 18 Draco thrusters provide roll control during reentry to keep it precisely on course toward the landing site before its parachutes deploy.

Designed for astronauts. Although this resupply mission carries only cargo, Dragon was designed from the outset to carry crew. Under a $440 million agreement with NASA, SpaceX is developing refinements for transporting crew, including seating for seven astronauts, the most advanced launch escape system ever developed, a propulsive landing system, environmental controls, and life-support systems. SpaceX expects to undertake its first crew demonstration in 2015.

True rumor. Dragon was named for the fictional Puff the Magic Dragon after critics in 2002 deemed SpaceX's founding goals fantastical.

ADVANCED TECHNOLOGY

Draco Thrusters
Dragon's 18 Draco thrusters permit orbital maneuvering and attitude control. Powered by nitrogen tetroxide/monomethylhydrazine (NTO/MMH) storable propellants; 90 lbf (400 N) thrust is used to control the approach to the ISS, power departure from the ISS, and control Dragon's attitude upon reentry.

Power
Two solar array wings on trunk (eight panels total) produce more than 5 kilowatts of power. Surplus power recharges Dragon's batteries for the periods when it is in darkness. In low-Earth orbit, Dragon is in darkness about 40% of the time.

Avionics
Dual fault-tolerant computing provides seamless real-time backups to all critical avionics components, providing one of the most reliable architectures to fly. The RIOs (remote input/output modules) provide a common computing platform with configurable input and output control cards. This architecture facilitates manufacturing and ensures the components' reliability.

Communications
- Communications between Dragon and the ISS are provided by the COTS UHF communications unit (CUCU). CUCU was delivered to the space station on STS-129.
- ISS crew command Dragon using the crew command panel (CCP).
- Dragon can also communicate on S-band via either tracking and data relay system (TDRSS) or ground stations.

Environmental Control System
- Astronauts will enter Dragon to remove cargo.
- Dragon's cabin is habitable, with air circulation, lighting, fire detection and suppression, air temperature control, pressure and humidity monitoring.

Thermal Protection System
- Primary heat shield: Tiled phenolic impregnated carbon ablator (PICA-X), fabricated in-house.
- Backshell: SpaceX Proprietary Ablative Material (SPAM).

Transporting Crew
While it initially is transporting cargo, Dragon was designed from the beginning to transport crew and is currently undergoing modifications to make this possible. Crew configuration will include life support systems, a crew escape system, and onboard controls that allow the crew to take control from the flight computer when needed. This focus on commonality between cargo and crew configurations minimizes the design effort and simplifies the human-rating process, allowing systems critical to Dragon crew safety and ISS safety to be fully tested on unmanned flights.

SpaceX Facilities

SPACE LAUNCH COMPLEX 40, CAPE CANAVERAL AIR FORCE STATION

Cape Canaveral, Florida

SpaceX's Space Launch Complex 40 at Cape Canaveral Air Force Station is a world-class launch site that builds on strong heritage: The site at the north end of the Cape was used for many years to launch Titan rockets, among the most powerful rockets in the US fleet. SpaceX took over the facility in May 2008.

The center of the complex is composed of the concrete launch pad/apron and flame exhaust duct. Surrounding the pad are four lightning towers, fuel storage tanks, and the integration hangar. Before launch, Falcon 9's stages and Dragon are housed inside the hangar, where Dragon is packed with cargo. A crane/lift system moves Falcon 9 into a transporter-erector system so that Dragon can be mated to the rocket. The vehicle is rolled from hangar to launch pad on fixed rails shortly before launch to minimize exposure to the elements.

SpaceX Launch Control, also at Cape Canaveral, is responsible for operating the Falcon 9 throughout the launch countdown.

SPACEX HEADQUARTERS

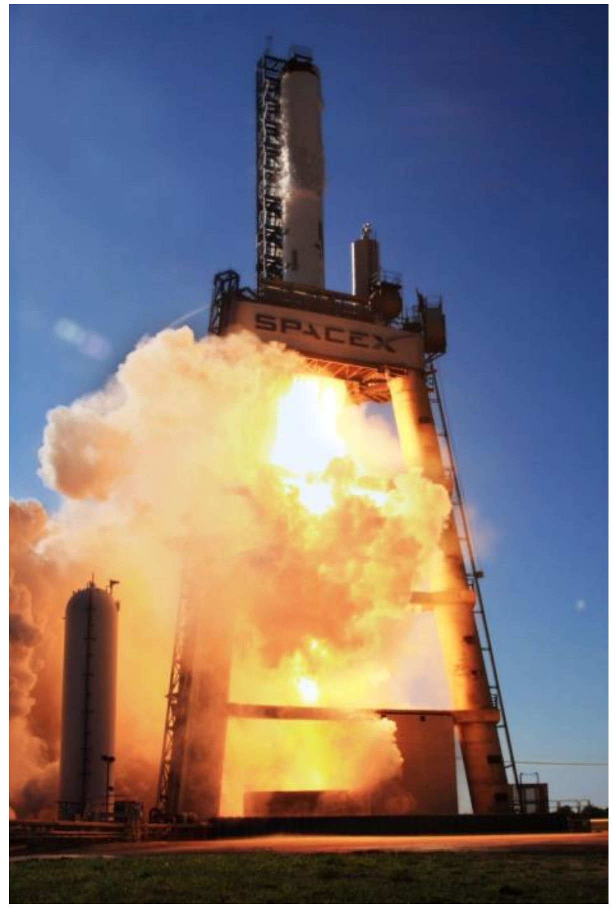
Hawthorne, California

SpaceX's rockets and spacecraft are designed and manufactured at the company's headquarters in Hawthorne, California – a complex that spans nearly one million square feet.

ROCKET DEVELOPMENT FACILITY

McGregor, Texas

Engines and structures are tested at a 900-acre state-of-the-art rocket development facility in McGregor, Texas.



SPACE LAUNCH COMPLEX 4E, VANDENBERG AIR FORCE BASE

Lompoc, California

SpaceX's Space Launch Complex 4E at Vandenberg Air Force Base in California is used for launches to high inclination and polar orbits, and will support launches of the Falcon Heavy.

SpaceX Company Overview

SpaceX designs, manufactures, and launches the world's most advanced rockets and spacecraft. The company was founded in 2002 by Elon Musk to revolutionize space transportation, with the ultimate goal of enabling people to live on other planets. Today, SpaceX is advancing the boundaries of space technology through its Falcon launch vehicles and Dragon spacecraft.

Transforming the Way Rockets Are Made

SpaceX's proven designs are poised to revolutionize access to space. Because SpaceX designs and manufactures its own rockets and spacecraft, the company is able to develop quickly, test rigorously, and maintain tight control over quality and cost. One of SpaceX's founding principles is that simplicity and reliability are closely coupled.

Making History

SpaceX has gained worldwide attention for a series of historic milestones. It is the only private company ever to return a spacecraft from low-Earth orbit, which it first accomplished in December 2010. The company made history again in May 2012 when its Dragon spacecraft attached to the International Space Station (ISS), exchanged cargo payloads, and returned safely to Earth—a technically challenging feat previously accomplished only by governments. SpaceX began official cargo resupply to the ISS in October 2012, with the first of 12 commercial resupply (CRS) missions.

Advancing the Future

Under a $1.6 billion contract with NASA, SpaceX will fly at least 9 more cargo supply missions to the ISS for a total of 12—and in the near future, SpaceX will carry crew as well. Dragon was designed from the outset to carry astronauts and now, under a $440 million agreement with NASA, SpaceX is making modifications to make Dragon crew-ready.

SpaceX is the world's fastest-growing provider of launch services. Profitable and cash-flow positive, the company has nearly 50 launches on its manifest, representing nearly $5 billion in contracts. These include commercial satellite launches as well as NASA missions.

Currently under development is the Falcon Heavy, which will be the world's most powerful rocket. All the while, SpaceX continues to work toward one of its key goals—developing reusable rockets, a feat that will transform space exploration by radically reducing its cost.

Key SpaceX Milestones

- **March 2002** SpaceX is incorporated
- **March 2006** First flight of SpaceX's Falcon 1 rocket
- **August 2006** NASA awards SpaceX $278 million to demonstrate delivery and return of cargo to ISS
- **September 2008** Falcon 1, SpaceX's prototype rocket, is the first privately developed liquid-fueled rocket to orbit Earth
- **December 2008** NASA awards SpaceX $1.6 billion contract for 12 ISS cargo resupply flights
- **July 2009** Falcon 1 becomes first privately developed rocket to deliver a commercial satellite into orbit
- **June 2010** First flight of SpaceX's Falcon 9 rocket, which successfully achieves Earth orbit
- **December 2010** On Falcon 9's second flight and the Dragon spacecraft's first, SpaceX becomes the first commercial company to launch a spacecraft into orbit and recover it successfully
- **May 2012** SpaceX's Dragon becomes first commercial spacecraft to attach to the ISS, deliver cargo, and return to Earth
- **August 2012** SpaceX wins $440 million NASA Space Act Agreement to develop Dragon to transport humans into space
- **October 2012** SpaceX completes first of 12 official cargo resupply missions to the ISS, beginning a new era of commercial space transport
- **September 2013** First flight of SpaceX's upgraded Falcon 9 rocket, with successful reentry of the first stage booster
- **December 2013** First flight of Falcon 9 to geosynchronous transfer orbit

Profile

SpaceX is a private company owned by management and employees, with minority investments from Founders Fund, Draper Fisher Jurvetson, and Valor Equity Partners. The company has more than 3,000 employees with its headquarters in Hawthorne, California; launch facilities at Cape Canaveral Air Force Station, Florida, and Vandenberg Air Force Base, California; a rocket development facility in McGregor, Texas; and offices in Houston, Texas; Chantilly, Virginia; and Washington, DC.

For more information, including SpaceX's Launch Manifest, visit the SpaceX website at www.spacex.com.

SpaceX Leadership

ELON MUSK
CEO and Chief Designer

As CEO and Chief Designer, Elon Musk oversees development of rockets and spacecraft for missions to Earth orbit and ultimately to other planets. The SpaceX Falcon 1 was the first privately developed liquid-fueled rocket to reach Earth orbit. In 2008, SpaceX won a NASA contract to use its Falcon 9 rocket and Dragon spacecraft to commercially provide the cargo transport function of the space shuttle, which was retired in 2011. In 2010, SpaceX became the first commercial company to successfully recover a spacecraft from Earth orbit with its Dragon spacecraft. And in 2012, SpaceX's Dragon spacecraft became the first commercial vehicle to successfully attach to the International Space Station and return cargo to Earth.

Prior to SpaceX, Elon cofounded PayPal, the world's leading Internet payment system, and served as the company's Chairman and CEO. Before PayPal, Elon cofounded Zip2, a provider of Internet software to the media industry.

He has a Bachelor of Science in physics from the University of Pennsylvania and a Bachelor of Arts in business from the Wharton School.

GWYNNE SHOTWELL
President and Chief Operating Officer

As President and COO of SpaceX, Gwynne Shotwell is responsible for day-to-day operations and for managing all customer and strategic relations to support company growth. She joined SpaceX in 2002 as Vice President of Business Development and built the Falcon vehicle family manifest to over 50 launches, representing nearly $5 billion in revenue.

Prior to joining SpaceX, Gwynne spent more than 10 years at the Aerospace Corporation where she held positions in Space Systems Engineering & Technology as well as Project Management. Gwynne was subsequently recruited to be Director of Microcosm's Space Systems Division, where she served on the executive committee and directed corporate business development.

Gwynne participates in a variety of STEM (Science, Technology, Engineering and Mathematics)-related programs, including the Frank J. Redd Student Scholarship Competition. Under her leadership the committee raised more than $350,000 in scholarships in 6 years.

Gwynne received, with honors, a Bachelor of Science and a Master of Science in mechanical engineering and applied mathematics from Northwestern University.